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IMPROVED PATTERNED MEDIA FOR PROBE-BASED HAMR

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Introduction

Magnetic recording technology has made tremendous gains in areal density, partially by introducing magnetoresistive heads and partially by scaling down the grain size of continuous longitudinal thin film media. However, further scaling will require a complete change in paradigm as the current technology will bring the grain sizes near the superparamagnetic limit. One solution to overcome this limitation is to use thermomagnetic recording also called "heat assisted magnetic recording" (HAMR) [2] wherein the media is heated locally to decrease the coercive field below the head write field. The major challenge here lies in the spatial localization of heat, which needs to be of the order of the bit cell size for appropriate SNR.

One option is to use probe-based heating sources. Here, most of the effort to date has been focused on the tip design/fabrication, while little attention has been given on the thermal properties of the media. In the light of a thermal modeling, we present here a novel concept of patterned media well suited for probe-based HAMR. This approach is based on the simultaneous use of low thermal conductivity nanoporous silicon and patterned media, the latter allowing both ultra-high storage densities and a quasi perfect lateral (e.g. inter bits) thermal insulation.

Thermal simulation

The modeling was based on the classical heat transfer equations (Fourier) and the use of effective thermal conductivity. We studied both the contact mode and the non-contact mode between a patterned media and a heated probe. In the non-contact mode, the tip is brought near the sample at distances below the mean free path of the molecules of the surrounding gas (60nm for air at 1 bar). Consequently, this ballistic heat transfer process is expected to be far more efficient than standard conduction. In addition, the absence of tip wear and often irreproducible thermal contact resistance should ease the integration. The expression of the heat flux per unit surface of the tip apex has been derived from kinetic theory of gas. Its value at 1 bar and for tip and media temperatures of 1000K and 300K, respectively, is $4.10^7 \text{ W.m}^{-2}.\text{K}^{-1}$. With tip apex in the range of $10 \times 10 \text{ nm}^2$, the incoming heat is not sufficient to heat the media because of important heat loss by the media itself which acts as a thermal sink. The situation is similar in the contact mode, despite a larger heat transfer.

To improve heating efficiency the pre-requisite is to use a substrate with a very low thermal conductivity. Nanoporous silicon with 70% porosity is known to allow thermal conductivity at 300K of only $0.29 \text{ W.m}^{-1}.\text{K}^{-1}$ [3], four time less than silicon oxide. Accordingly, in the

contact mode, and considering a nanoscale thermal contact conductance between tip and sample of $100 \text{ MW.m}^{-2}.\text{K}^{-1}$ [4], the media temperature can be as high as 750K (compared to 302K when the substrate is silicon) with an input power of 40 mW (corresponding to a tip temperature in air of 1000 K). This is by far enough to decrease the writing field below 1000 Oe (fig.1). The power needed is then only 10mW.

Media fabrication

We first prepare patterned silicon mesa as described in [1]. Then porous silicon is formed by anodic oxydation of silicon in an HF-ethanol solution and magnetic layers are deposited by magnetron sputtering. As magnetic properties of multilayers such as CoPt, are known to be very much surface roughness dependent, we studied the influence of the porous silicon surface on the magnetic properties of the multilayer. The porous silicon surface appears flat with a very low rms roughness of 20 angstroms. Its structure, however, is particular with a random array of nanopores. The optimal magnetic properties of films deposited on continuous porous substrates have been obtained for a $\text{Pt}_{1.0\text{nm}}/(\text{Co}_{0.5\text{nm}}/\text{Pt}_{1.8\text{nm}})_4$ multilayer. As shown in figure 2, the hysteresis loop is square shaped and the coercive field is only slightly different from that of the same layer deposited on regular silicon.

The next step will consist in studying magnetic properties of porous patterned media and performing the first writing tests.

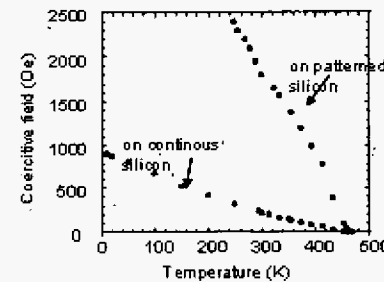


Fig 1. : Coercive field of $\text{Pt}_{1.8\text{nm}}/(\text{Co}_{0.5\text{nm}}/\text{Pt}_{1.8\text{nm}})_4$ on patterned and continuous silicon versus temperature.

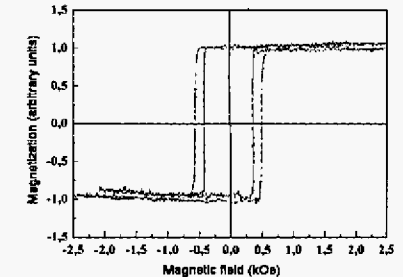


Fig 2. : Polar Kerr hysteresis loop of $\text{Pt}_{1.0\text{nm}}/(\text{Co}_{0.5\text{nm}}/\text{Pt}_{1.8\text{nm}})_4$ on porous layer (red curve) and on silicon (black curve)

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